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RECLAIMING USED PIPE FOR OIL-FIELD OPERATIONS WITH CEMENT LINING

BY

PETER GRANDONE

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By Peter Grandone[2]

CONTENTS

	Page
troduction	2
knowledgments	2
ants in the Mid-Continent area for lining pipe with cement	2
eories of protection by lining with cement	3
reparing used pipe for lining with cement	3
ethod of applying cement lining in pipe	4
Centrifugal process	4
Setting time for cement lining	5
Type and composition of cements used	5
Thickness of cement lining	6
Cement lining of pipe fittings	6
st of lining pipe with cement	7
ses of cement-lined pipe in oil-field operations	8
Water-flooding projects	8
Brine-disposal systems	9
Oil-gathering lines	10
mmary	10

TABLES

ble		Page
.	Analyses of raw cements	5
2.	Analysis of iron blast-furnace slag	6
3.	Dimensions and weights of cement-lined pipe (for new pipe)	7

ILLUSTRATIONS

gure		Follows Page
1.	Machine for straightening crooked pipe	2
2.	Machine for cleaning external surface of pipe	2
3.	Machine for lining pipe with cement by centrifugal process	4

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55

INTRODUCTION

Steel and iron pipe lined with cement to protect it against corrosi has been used in the municipal water systems of the New England States si about 1870. In most recent years, the petroleum industry adopted cement-lined pipe to forestall corrosion, particularly in those areas where larg quantities of corrosive brines and hydrogen sulfide are associated with t oil produced. Many of the oil companies had on hand large quantities of corroded pipe, normally disposed of as scrap, which could be cleaned, lin with cement, and returned to service. It was soon learned that after the so-called scrap pipe was lined with cement much of it could serve fully a well as new cement-lined pipe.

The demand for lining used pipe with cement resulted in the establis ment of several processing plants in the Mid-Continent oil-producing area Today six cement-lining plants serve the areas - three in Oklahoma and on each in Kansas, Texas, and Illinois. All of these plants have lined larg quantities of used pipe for the brine-disposal systems of western Kansas, Illinois, and east Texas and also for the operators of water-flooding pro jects in northeastern Oklahoma and southeastern Kansas, where large quant ties of brine and fresh water are being injected into the oil-bearing formations as a secondary oil-recovery method. Since war demands during the past 2 years have created an acute shortage of steel, the need of reclaiming used pipe for the expansion of oil-producing operations has beco more evident than ever before. Thus the new industry (about 6 years old) lining used pipe with cement - is saving large quantities of steel at a critical time by reclaiming used pipe and preventing further corrosion.

ACKNOWLEDGMENTS

This report on lining used oil-field pipe with cement was prepared u the general supervision of R. A. Cattell, chief engineer, Petroleum and N ral Gas Division, Bureau of Mines, Washington, D. C., and N. A. C. Smith, former supervising engineer, Petroleum Experiment Station, Bureau of Mine Bartlesville, Okla. and under the direct supervision of Ludwig Schmidt, senior petroleum engineer, Bureau of Mines, Bartlesville, Okla.

Gratefully acknowledged is the cooperation received from the manufac turers of cement-lined pipe in the Mid-Continent area and from the offici of the several oil companies who contributed information on the uses of cement-lined pipe on their properties.

The writer is indebted to the following members of the Bureau of Min for constructive review of the manuscript: Gustav Wade, C. K. Eilerts, a R. V. Smith, Bartlesville, Okla.; and C. J. Wilhelm, Franklin, Pa.

PLANTS IN THE MID-CONTINENT AREA FOR LINING PIPE WITH CEMENT

The location of plants for lining pipe with cement, with reference t those oil-producing areas where large quantities of used pipe are availab for reclaiming, is important because of the cost of shipping the pipe to

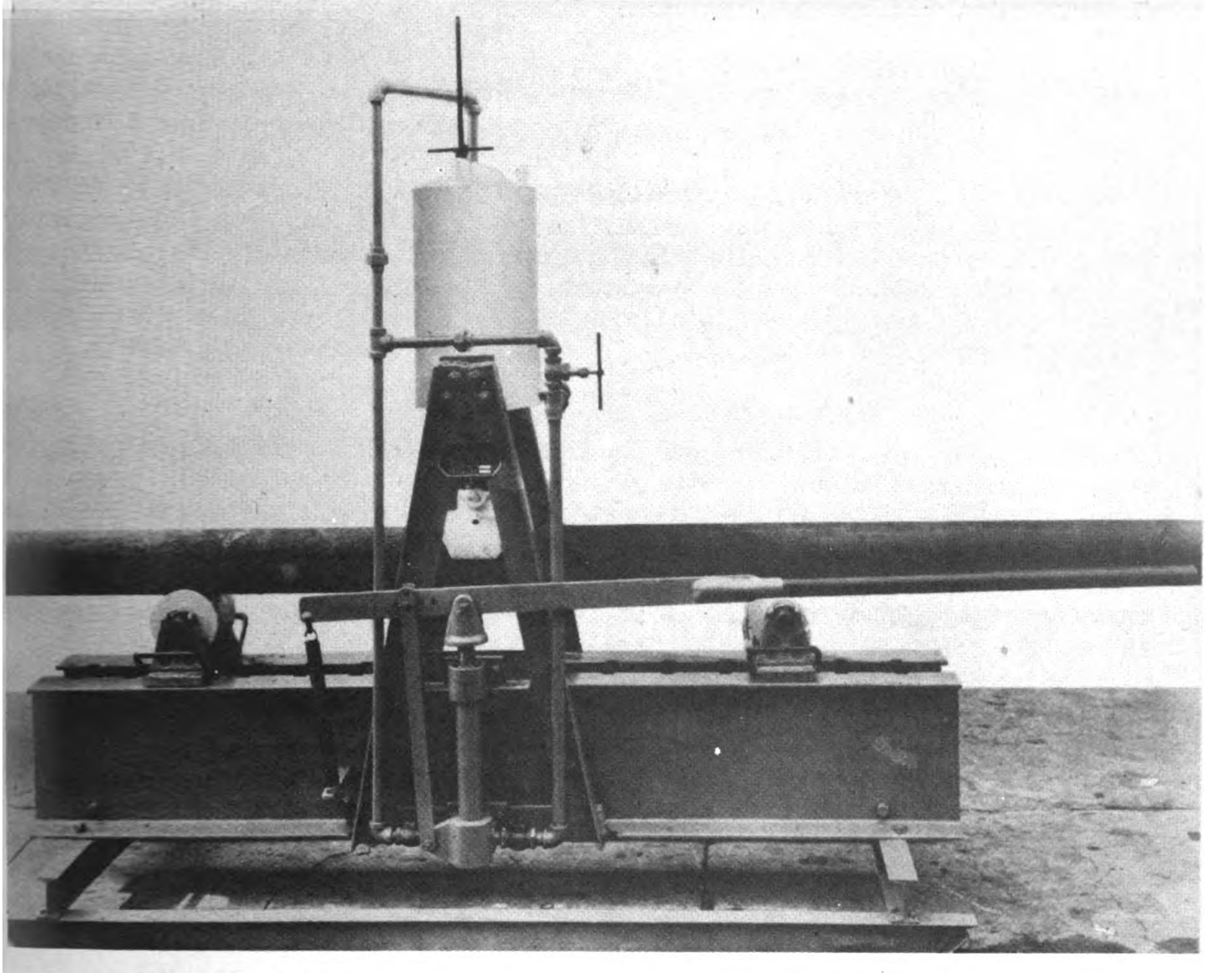

FIGURE 1.- Machine for straightening crooked pipe.

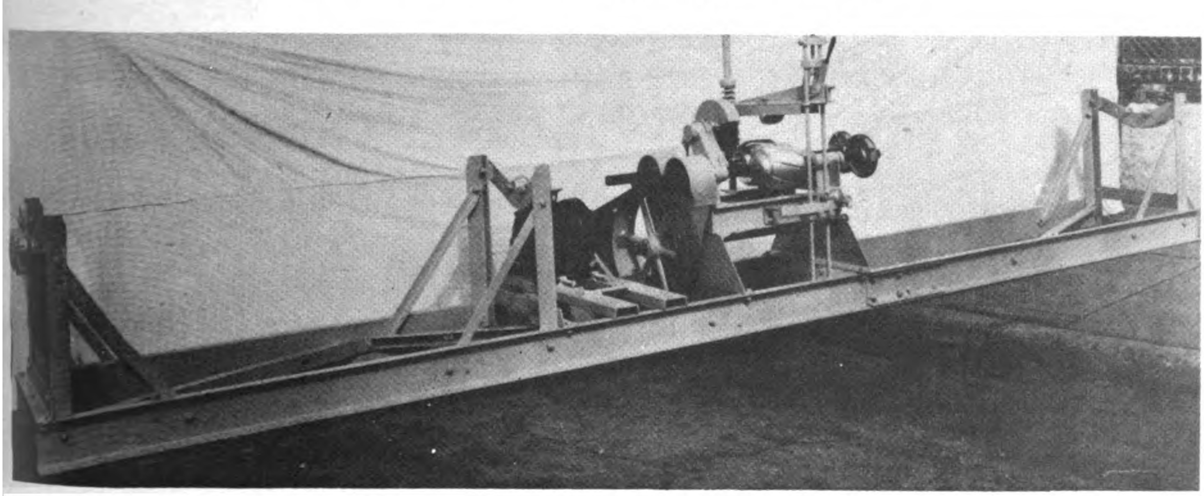

FIGURE 2.- Machine for cleaning external surface of pipe.

rom the plants. In the Mid-Continent oil-producing areas, much of the pipe o be reclaimed is found in the older oil fields of northeastern Oklahoma nd southeastern Kansas and in those areas where corrosive brines and hydroen sulfide are produced with the oil. In the areas mentioned, cement-lined pe is widely used in water-flooding operations for the secondary recovery f oil and in brine-disposal systems.

To meet the demand for reclaiming used pipe for oil-field operations here are two plants for lining pipe with cement in Tulsa, Okla., one in wata, Okla., one in Iola, Kans., one in Salem, Ill., and one in Gladewater, ex. These plants started operations during or after 1940 and are cementining new and used pipe. A few of the plants also purchase used oil-field ipe for lining with cement and therefore are in a position to supply cementined used pipe to the market.

THEORIES OF PROTECTION BY LINING WITH CEMENT

It long has been known that the manner in which a cement coating proects steel is both physical and chemical, the cement acting as a protective ayer and as a neutralizing alkali. In 1927 Carson[3] pointed out that the rotection afforded against corrosion of steel by cement linings is dependent pon the blanketing effect of the cement layer and the alkalinity of the lime n the cement in contact with the metal wall. The permanence of a cement ining therefore is related in part to the solubility of the constituents of he cement, particularly the calcium compounds. Some of the dissolved contituents in oil-field brines, such as magnesium sulfate, hydrogen sulfide, nd iron compounds, tend to react with the calcium compounds in portland ement and may cause the lining to deteriorate and lose its protective effect f the reactions progress too rapidly or too extensively throughout the cement ayer. Consequently, processors of cement lining for pipe have developed ements with properties that are particularly resistant to the deteriorating ffects of oil-field fluids.

PREPARING USED PIPE FOR LINING WITH CEMENT

The successful application of cement lining to used pipe depends in part n the condition of the pipe itself. All used pipe acceptable for cement ining must be straight and free of holes. Some processors of cement lining re equipped with machines (fig. 1) to straighten crooked pipe and with welding equipment to spot-weld holes, but usually this extra service is done lsewhere before the pipe is shipped to the processor. Used pipe commonly s classified in three grades, No. 1, No. 2, and No. 3. The No. 1 grade is ree of pit holes, has good threads, and responds to the "hammer" test (rings learly when tapped with a peen hammer). When cement-lined, the No. 1 grade s recommended for working pressures equivalent to those for new pipe. The o. 2 grade of pipe is not free of pits and may have a few holes through the all, but these holes must be spot-welded before the cement lining is applied.

/ Carson, Harry J., Cement-Lined Water Mains: Ind. and Eng. Chem., vol. 19, 1927, pp. 781-783.

Some processors do not accept the No. 2 grade if the holes to be spot-wel exceed 1/8 inch in diameter, because pipe corroded to that extent is considered too weak for service. The pipe need not respond clearly to the "hammer" test, and although the threads may not be perfect it is recommen that the pipe be "shopped" for new threads before the lining is applied b cause worn threads frequently develop leaks. No. 2 pipe is recommended f service where the working pressure is much lower than that required for pipe, such as for oil- and brine-gathering lines. The No. 3 grade of us pipe meets none of the above requirements and consequently is not suitab for lining with cement or for further service.

To insure a tight bond between metal and cement, the inside surface all used pipe must be cleaned thoroughly. It also is desirable to clean external surface to expose all holes. The external surface usually is cl by means of a pipe cleaning machine (fig. 2); the internal surface may be cleaned by one or more of several methods, including sand blasting, direc heat, steam washing, and mechanical scraping. Usually it is necessary f to heat used oil-field pipe over a flame or with a torch to burn out oil and then to remove the scale.

METHOD OF APPLYING CEMENT LINING IN PIPE

The process of lining metal pipe and tubing with hydraulic cements d back to about 1876, according to various accounts. The cement mixture is distributed within the pipe by the centrifugal force developed by rotatin the pipe at a high speed, thus producing a compact lining of uniform thi ness with a smooth surface. The composition and mixing of the cement, th rotational speed of the pipe, and curing during the setting period of th cement are all important considerations contributing to a satisfactory l and require special knowledge and practical experience.

Centrifugal Process

For cement-lining pipe by the centrifugal process, a measured quant of mixed cement is charged into the pipe in a uniform ridge throughout t length of the pipe; the proper quantity of cement charged into each size pipe to give the appropriate lining thickness (see table 3) is determine by practice. Next, special bushings (see fig. 3) are screwed on the end of the pipe to provide "stops" for the lining flush with the ends of the and to serve as guides for the thickness of the lining. The pipe then i placed on the rolling machine (fig. 3), where the cement lining is spre uniformly by rotating the pipe at a peripheral speed of 500 to 600 feet minute until uniformity is obtained. Usually a mandrel, of appropriate meter, is pushed through the pipe to "size" the lining, and the pipe is rotated a second time as before. The centrifugal force developed in the rotating operation is enough to press excess water out of the cement so the lining is compact enough to withstand handling of the lined pipe fr the machine to the curing racks.

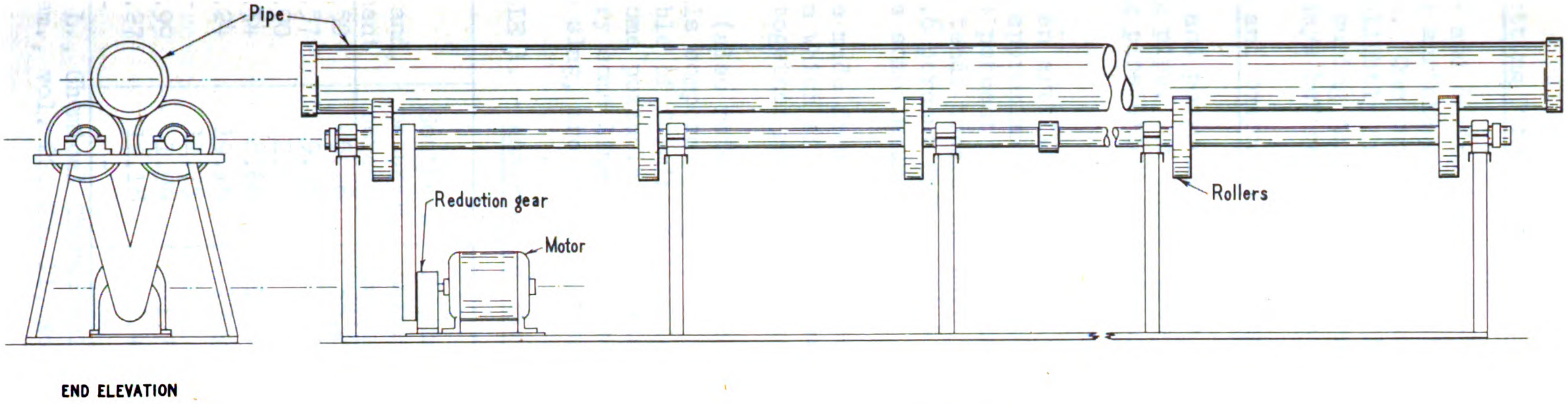

FIGURE 3.- MACHINE FOR LINING PIPE WITH CEMENT BY CENTRIFUGAL PROCESS.

Setting Time for Cement Lining

Proper setting time and curing method for the cement lining in pipe are very important to reduce shrinkage to negligible proportions and to assure a high mechanical strength. One curing method used is to place the newly lined pipe on racks that are slightly inclined and flow water through the pipes occasionally during the curing period. Most processors allow lined pipe to set or cure for 3 to 5 days before shipment is made.

Type and Composition of Cements Used

Portland, natural, and pozzuolana cements, including blast-furnace slags, are available for lining pipe. Of these three, the pozzuolana type is most commonly used for lining pipe because of its higher resistance to corrosive fluids.

Portland cement is an artificial chemical product of fairly definite composition, containing approximately 59 to 65 percent lime, 19 to 25 percent silica, and 6 to 14 percent iron oxide and alumina. The composition of the finished product tends toward the pure tricalcic silicate ($3CaO,SiO_2$), which corresponds to 73.6 percent CaO and 26.4 percent SiO_2. Actually portland cement contains some impurities.

Natural cements are made from clayey limestones carrying 13 to 35 percent clayey material, in which silica varies between 10 to 22 percent and alumina and iron oxide together may vary between 4 to 16 percent.

Pozzuolana cements (also referred to as pozzolanic or pozzolan cement) include natural materials composed largely of silica and alumina with some iron oxide and are capable of forming hydraulic cements simply on being mixed with lime. Actually, some pozzuolana-type cements, such as the slags used in cement manufacture, carry some lime. Analyses of the foregoing cements, including a blast-furnace slag, are given in tables 1 and 2.

TABLE 1. - Analyses of raw cements[1/]

Constituent	Portland, percent	Southern natural, percent	Northern natural, percent	Alumina cement, percent	Pozzuolana before adding lime, percent
CaO	63.50	45.26	35.26	33.0	10.0
MgO	2.57	9.75	17.39	0.60	3.0
Fe_2O_3	2.90	2.04	5.15	13.10	15.5
Al_2O_3	7.34	8.66	11.45	33.4	16.5
SiO_2	20.24	19.26	19.98	2.80	46.0
CO_2	-	11.75	-	-	-
SO_3	1.99	1.99	1.75	.30	-
Ignition (loss).	1.27	12.18	6.40	4.4	-
Insoluble	-	-	-	15.0	5.0

[1/] After Chappell, E. L., Chemical Characteristics of Cement Pipe Lining: Ind. and Eng. Chem., vol. 22, No. 11, November 1930, p. 1203.

455

TABLE 2. - Analysis of iron blast-furnace slag[1]

Constituent	Percent
CaO	32.75
MgO	5.25
Fe_2O_3, FeO	0.75
Al_2O_3	28.00
SiO_2	30.00
CaS	1.90

[1] As reported by Eckel, E. C., Cements, Limes, and Plasters: John Wiley & Sons, Inc., New York, 3d ed., 1928, p. 321.

Careful investigations on the composition of cements used for lini pipe have shown that the original types of linings were not entirely sat factory because the cements were relatively soluble owing to their high content and because many cement linings underwent appreciable shrinkage ing setting. This shrinkage caused loosening and cracking of the lining with consequent loss of the protective value. According to Chappell,[4] reported on the condition of the cement lining of pipe that had been in vice for more than 50 years in the water system at Worcester, Mass., all the lime content of the cement was found to have been displaced by iron hydroxide. Processors of cement lining for pipe also have found that oi field brines containing appreciable amounts of magnesium sulfate and hyd sulfide are particularly destructive to cement linings that have a relat high lime content. Magnesium sulfate reacts with lime to deposit calci sulfate, and although calcium sulfate itself may contribute some protec value in the cement lining, "leaching" of the cement by the magnesium su and expansion of the calcium sulfate will result in a softening and cru of the lining if the cement has a high lime content. For the above reas most processors of cement lining no longer employ straight portland cem (table 1) for lining pipe for oil-field operations and are commonly usin pozzuolana materials that have low lime and high silica contents.

Thickness of Cement Lining

The sizes of pipe lined by the cement-lining processors range from inch to 20 inches in diameter, and the thickness of the lining is varie the size of the pipe. The lining applied to 1/2-inch pipe is 0.06 inch thickness and is increased to 0.25-inch thickness for 6- to 8-inch pipe to 0.312 inch for pipe over 8 inches in diameter. A list of lining thic nesses, inside diameters, and weights of lining per linear foot of pipe pipe sizes 1/2 inch to 12 inches in diameter is shown in table 3.

Cement Lining of Pipe Fittings

To afford complete protection of the metal in a cement-lined pipe it also is necessary to use cement-lined fittings. Pipe nipples are co lined by the centrifugal process in the same manner as the longer lengt pipe. Other fittings, such as ells, tees, and crosses, however, are li hand with the aid of cores or special equipment. In applying the lining fittings that have internal threads, care is used to terminate the lin well below the base of the threads.

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[4] Chappell, E. L., Chemical Characteristics of Cement Pipe Lining: and Eng. Chem., vol. 22, No. 11, November 1930, p. 1204.

TABLE 3. - Dimensions and weights of cement-lined pipe
(for new pipe)

Nominal size, inches	Internal diameter		Thickness of lining, inch	Weight per foot	
	Unlined, inches	Cement-lined, inches		Unlined, pounds	Cement-lined, pounds
0.50	0.622	0.484	0.06	0.85	0.97
.75	.824	.686	.06	1.13	1.29
1	1.049	.896	.06	1.67	1.91
1.25	1.380	1.175	.08	2.27	2.68
1.50	1.610	1.405	.08	2.71	3.20
2	2.067	1.780	.10	3.65	4.53
2.50	2.469	2.182	.10	5.79	6.85
3	3.068	2.725	.125	7.57	9.15
3.50	3.548	3.205	.125	9.10	10.95
4	4.026	3.620	.156	10.79	13.26
5	5.047	4.548	.187	14.61	18.43
6	6.065	5.440	.250	18.97	24.70
8	8.071	7.446	.250	24.69	32.41
8	7.981	7.356	.250	28.55	36.18
0	10.192	9.443	.312	31.20	42.91
0	10.136	9.387	.312	34.24	45.88
0	10.020	9.271	.312	40.48	51.99
2	12.090	11.341	.312	43.77	57.74
2	12.000	11.251	.312	49.56	63.43

Pipe collars usually are not cement-lined individually because of the mall exposed area between the threaded sections but usually are partly lined ith the pipe when in place on the pipe. When assembling pipe it is necessary o apply cement over the exposed metal at the threads to attain complete proection. Some users of cement-lined pipe prefer to use plastic type cements o seal the threads so that the pipe may be disconnected with less danger of racturing the adjoining cement lining. A commoner method of sealing the hreads consists of applying the required amount of cement slurry over the xposed metal as the pipe is assembled and then drawing a mandrel through the assage so as to compress and smooth the cement over the recess.

COST OF LINING PIPE WITH CEMENT

The cost of lining pipe with cement, of course, is important to oil opertors if any economy is to be realized through the salvage of used pipe. side from the labor cost of replacing badly worn pipe, some of the costs that nter into the salvage of pipe in addition to the cement-lining cost are shopping" cost (straightening of pipe and cutting of new threads) and ransportation to and from the cement-lining plant.

The weights of various sizes of new pipe, with and without cement lining, o be used in computing shipping weights, are given in table 3. Costs of ement-lining the commoner sizes of pipe at the plant, as reported by oil perators in 1944, are as follows:

Pipe size, inches	Cost per foot, dollar
1.5	0.075
2.0	.085
3.0	.125
4.0	.17
6 to 7	.25

USES OF CEMENT-LINED PIPE IN OIL-FIELD OPERATIONS

Cement-lined steel pipe is used primarily for carrying waters and sc
tions that corrode unprotected steel pipe or for tuberculating waters tha
tend to clog the pipe. Processors of cement lining use cement materials
produce a lining that is highly resistant to the deteriorating effects of
field fluids. Special curing treatment reduces shrinkage of the lining t
negligible proportions and gives it a high mechanical strength so that nc
unusual precautions are necessary for handling cement-lined pipe. Pipe l
with cement may be cut and threaded the same as ordinary pipe. The princ
uses of cement-lined pipe in petroleum production are for water-flooding
projects, for brine-disposal systems, and for oil-gathering lines where t
fluids handled are very corrosive because of the presence of brine and hy
gen sulfide.

Water-Flooding Projects

The injection of water into oil-bearing formations as a means of sti
lating the recovery of oil is widely practiced in northeastern Oklahoma a
southeastern Kansas. Field development for water flooding requires close
spaced input and producing wells (usually 330 feet between the like wells
a five-spot pattern) and an intricate system of water lines for deliverin
water to the input wells. The source of the water may be fresh water fr
streams, surface ponds, or wells, brine produced with the oil, or mixture
of fresh water and brine. To prevent corrosion and avert frequent replac
ment of the water lines, many operators of water floods have resorted to
use of cement-lined pipe for the water-distribution lines and cement-line
tubing in the input wells. In some instances where the operators of wate
floods flow the oil from producing wells, cement-lined tubing and cement-
lined oil-gathering lines also are used. Most of the cement-lined surfac
pipe used in water floods is reclaimed pipe, principally because used pip
usually is available in areas where secondary recovery of oil is practice
and because of the shortage of steel. Moreover, water flooding, like oth
secondary recovery methods, usually is operated on a narrow margin of pr
and seldom justifies the use of new and costly materials. Some operators
prefer to install only cement-lined new tubing in wells to lessen the cha
of leaks developing at the threaded joints. Wear of threads on used pipe
cause the threads to seat against the end of cement lining and result in
leaky joint. Surface lines, of course, may be tested for leaks when ass
and inspected periodically, but leaks at the threaded joints of tubing in
stalled in a well can be found and repaired only with difficulty and at c
siderable cost. A common practice in water flooding is to cement the tub
in the well with several sacks of cement above the packer, so as to withs

the pressure of injected water; as a result, the tubing cannot be removed readily for examination.

One operator of extensive water floods in Nowata County, Okla., employs cement-lined used pipe exclusively for both the water and oil surface lines and cement-lined new tubing in the input and producing wells. The practice of this operator is to electric-weld all joints in the surface lines, leaving only a very narrow area of exposed metal. It is found that electric welding confines the heat in the narrow region at the weld, preventing cracking and crumbling of the cement lining, and that the narrow area of exposed metal at the welded joint readily becomes encrusted with sediment when fresh water is pumped through the pipe. Electric welding of the joints in the surface also permits directional changes in the line without the use of cumbersome swing elbow fittings which increase the resistance to flow through the pipe.

This operator has reclaimed much of the pipe used for surface lines in Nowata County by having the pipe cement-lined - a salvage of about 10,000 feet of pipe a month. Moreover, some of the reclaimed, cement-lined pipe has been in service for about 6 years, operating at line pressures ranging from 400 to 500 pounds per square inch, and still is giving good service. Although this operator can use cement-lined tubing in the producing wells that flow the oil, it is not practical to use cement-lined tubing in pumping wells because the action of the pump rods will damage the lining.

Brine-Disposal Systems

The common practice of disposing of oil-field brines in inland regions, where appreciable quantities of such brines are produced with the oil, is by injection into subsurface formations that already contain mineralized waters. Many oil-field brines, such as those produced from the Arbuckle formation of western Kansas and from the Woodbine formation in east Texas, are particularly corrosive to steel because of either the mineral salts or hydrogen sulfide. As a protection against corrosion of surface lines for transporting the brines in disposal systems to disposal wells, both cement-lined pipe and pipe of corrosion-resistant materials (cement-asbestos and fiber-asphalt) are commonly used. In disposal wells, however, it is necessary to use steel tubing because of the mechanical strength required; thus cement-lined tubing is commonly used to protect against corrosive brines.

A large oil producer with extensive holdings in western Kansas is operating 12 brine-disposal systems in 9 fields and uses tubing in the disposal wells consisting of about 25,300 feet of cement-lined new tubing and about 4,500 feet of cement-lined used tubing, mostly 3- and 4-inch in size. The cement-lined well tubing has been in service for more than 1 year and is giving satisfactory service. Much of the cement-lined new pipe and new tubing used by this operator has been cement-lined locally to save on the cost of shipping cement-lined pipe from the eastern factories.

Oil-Gathering Lines

In areas where large quantities of brine and hydrogen sulfide are produced with oil, corrosion of the oil-gathering lines often is very serious Some operators are reclaiming much of their corroded gathering lines by ha them reconditioned, cement-lined, and restored to service. As mentioned p viously, some operators of water-flooding projects use cement-lined pipe f the oil-gathering lines as well as for water-injection lines. The quantit of cement-lined used pipe in service in any area is not known, but substan quantities are being used by some oil operators in western Kansas and by t water-flooding operators of northeastern Oklahoma and southeastern Kansas.

SUMMARY

Large quantities of used and badly corroded oil-field pipe are being reclaimed by the cement-lining process and returned to service, thus effec ing a substantial saving in steel. The process has enabled many oil producers to continue and even expand operations at lower costs, and to prote pipe against further corrosion, particularly in those areas where corrosi brines and hydrogen sulfide mixtures are handled. In many instances, cem lined used pipe serves equally as well as cement-lined new pipe.

Cement-lined pipe as now produced is lined with cement materials tha are highly resistant to corrosive fluids and to tuberculating waters that tend to clog the pipe. The lining is applied in a uniformly thick, smoot layer by a centrifugal process, is little affected by sudden temperature changes, and has high mechanical strength, so that no unusual handling pr cautions are necessary. Lined pipe may be cut and threaded the same as o nary pipe. Pipe fittings also are cement-lined, and when the lined pipe assembled the exposed metal remaining at the threaded joints usually is s over by plastering the joint with cement slurry followed by drawing a man through the passage to compress and smoothen the cement over the joint. operators prefer to apply plastic-type cements over threaded joints to fa tate unscrewing the joint without breaking the cement lining adjacent to

The principal uses of cement-lined pipe in oil-field operations are water-flooding oil-bearing formations as a secondary recovery method, for brine-disposal systems, and for oil-gathering lines where the fluids hand are particularly corrosive to steel. In some water-flooding projects, ce lined pipe is used for both water and oil lines. Cement-lined tubing is commonly used in brine-disposal wells and in the water-input wells of wat flooding developments. When oil is produced by flowing in a water-floodi project, cement-lined tubing also may be used in the producing wells, but scraping action of the pump rods in pumping wells will damage the cement

At present, six plants for lining oil-field pipe with cement, in Okl Kansas, Texas, and Illinois, serve principally the oil operators in those States. No estimate can be made of the quantity of used pipe cement-lin these plants, but it is known that substantial quantities have been lined the water-flooding operators of northeastern Oklahoma and southeastern K and for brine-disposal systems in western Kansas and east Texas.